Reservation of interconnection capacity for imbalance netting: case for the Belgian-Dutch border

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1 Introduction

In order to combat recent and future issues concerning the changing electricity system, the creation of a European wide electricity market was proposed in 2009. However, only focusing on the wholesale market, where electricity itself is exchanged, will not ensure an efficient system [1]. Therefore, the markets for ancillary services are also considered. These ancillary services consist of activities such as voltage control and frequency control (i.e. balancing reserves). The goal was to couple all these markets across Europe to achieve a more efficient electricity market, in rule with the Third Energy package proposed by the EU with the help of a new organisation, the European Network of Transmission System Operators (ENTSO-E) [2].

However, the implementation has not progressed equally for all markets. For the wholesale market, countries have harmonised their different markets so that cross-border exchange is a valuable part of the market. These markets are organised according to their respective region such as Central Western Europe or Northern Europe [3]. For the balancing markets, this implementation is lagging because current balancing markets differentiate on aspects such as gate closure times, minimum up times and load participation. Therefore, ENTSO-E made harmonisation of these markets an important target [4].

There are several reasons why a harmonised balancing market is important. This will increase benefits for both Transmission System Operators (TSOs) and society as the number of suppliers increase, which in turn increases competition and reduces prices [5], [6]. Furthermore, a larger number of suppliers will also enhance operational security [6].

This paper studies how the imbalance market is influenced by the availability of interconnection capacity. By reserving capacity upfront, there is an increase in imbalance netting potential and thus in cost savings from reducing the need to activate balancing reserves. Furthermore, reliability limits currently imposed on cross-border balancing exchanges further hamper the potential of imbalance netting. The importance of this limit is also studied in this paper.

The structure of this paper is as follows. Section 2 presents the balancing market organisation. Section 3 explains what imbalance netting is and how this works. Section 4 explains the model that is used to research this. Section 5 presents the results. Section 6 concludes this paper and gives suggestions for future work.

2 Balancing market organisation

2.1 Balancing phases

There are three phases in the balancing market structure [7]. First, each TSO calculates the amount of reserves that are needed. This depends on the type of products and the specifics of the country. E.g. on the one hand, for Frequency Containment Reserves (FCR), the sizing is coordinated by ENTSO-E so the TSOs themselves are not responsible for this. On the other hand, not every country is required to size, and procure, Replacement Reserves (RR) [8]. This explains why reserve needs differ across Europe: some countries focus on Automatic Frequency Restoration Reserves (aFRR) for most of their needs, others use Manual Frequency Restoration Reserves (mFRR) [9]. An explanation of these products follows in Section 2.2

Second, the reserves sized in the first step are procured on the market. This procurement makes sure that reserves will be available to be activated if necessary, they are in stand-by mode. Most reserves get a reservation price, which is based on the amount of capacity that is reserved, regardless of eventual activation. This procurement step is different for most countries as all the markets differ from each other. Furthermore, the frequency of the procurements also differ: this can go from weekly to annual [10].

Third and last, the reserves that were procured can be activated if necessary in real-time. When activated, these reserves get an activation price that is based on the energy that they delivered. Two activation schemes are used: pro-rata and merit order. With pro-rata, all the contracted reserves are activated, regardless of their activation price. However, they are only activated *pro-rata* their share in the total amount of procured reserves. In this way, all available ramping speed is used [9]. For merit order, the reserves are activated according to a merit order scheme where the cheapest ones, in terms of activation price, are activated first [9].

During this last phase, there is a strict sequence in how the reserves are activated. First, imbalance netting is evaluated. This will be further explained in Section 3 . Second, only after the possibilities of imbalance netting are exhausted, the other options of activating aFRR and, if necessary, activating mFRR are used.

2.2 Balancing products

To maintain the balance between production and consumption, and thus the frequency, in an electrical system, TSOs can choose from four different kind of products: FCR, aFRR, mFRR and RR (see Figure 1) [4], [11].

FCR, previously called primary reserves, are the first line of defence against frequency deviations. They have to stabilise these deviations almost immediately to make sure that the problem is contained, hence their name. Not surprisingly, the reaction times are very short (i.e. 15 seconds) [10].

FRR have the goal of relieving FCR from their task in order for them to be freed up to counter new deviations. First, the aFRR, or secondary reserves, are activated. If these cannot restore the balance, the TSO sends out a signal to the suppliers to inform them to manually activate their mFRR (tertiary reserves). The reaction times of this product differ between countries but are commonly below 15 minutes [10].

RR are the last option for TSOs to balance the system with reserve products. These will be activated in case of major disturbances in order to relieve aFRR after 15 minutes so that they are ready for further frequency deviations [12].

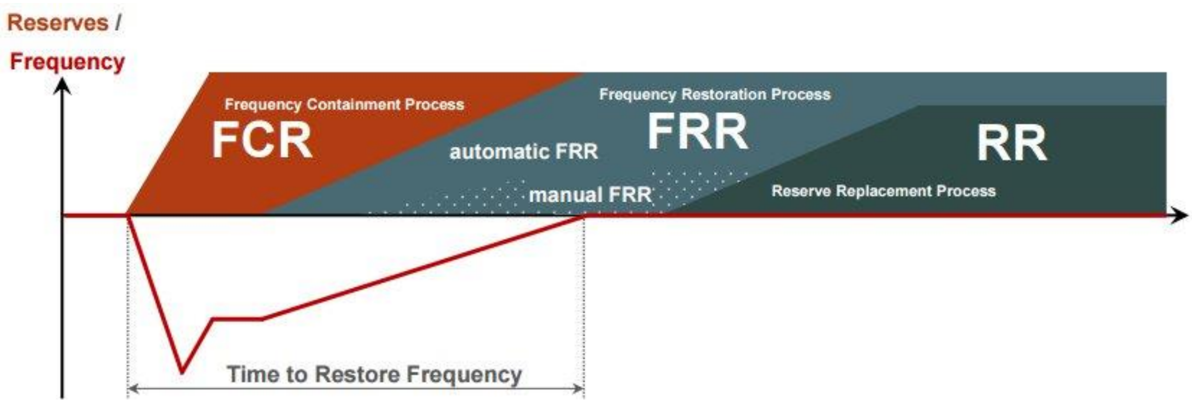

Figure 1 Overview of balancing products [13]

2.3 International Grid Control Cooperation

Several projects of balancing market integration are already present in Europe [14]. For FCR, which is already sized European wide, a large coordinated market is present in Western Europe (Germany, the Netherlands, Belgium, Switzerland and Austria) with more countries (France and Denmark) to follow [15], [16]. Furthermore, imbalance netting is in place thanks to the International Grid Control Cooperation (IGCC) [17].

IGCC started as a cooperation between the four German TSOs in order to optimise the activation of aFRR [18]. Since 2011, this cooperation has extended to foreign TSOs in Denmark, the Netherlands, Switzerland, the Czech Republic, Belgium, Austria and France. The development consists of four sequential modules [19]:

1. Preventing counteracting balancing energy activation

If two neighbouring control areas have imbalance volumes in opposite directions, the respective TSOs can choose to exchange these volumes with each other. This will reduce the amount of total imbalance volumes in the system. This results in not only fewer reserves to be activated, but also a reduction of the moments where neighbouring TSOs activate aFRR in opposite directions, which is a clear point of inefficiency [8]. This is also called imbalance netting and is further explained in Section 3

2. Common dimensioning of control reserve

In this module, TSOs will cooperate in the first phase of the balancing market. Instead of only taking their own control area into account to size their reserves, TSOs will work together to size reserves for the combined control area of all cooperating TSOs. Thanks to pooling effects, the overall amount of required reserves will decrease, which also reduces costs [20].

3. Common procurement of aFRR

Related to the second phase of the balancing market, TSOs will not only size their reserves in cooperation with each other but also procure these together. However, for this phase to be successful, a decent harmonisation of these markets is necessary as balancing products may not be able to enter every market due to differences in characteristics. Two approaches are possible for this procurement. First, TSO-BSP (Balance Service Provider) trading occurs when BSPs from one country exchange their reserve products directly with the TSO of another country, without interactions with their own TSO. Second, with the TSO-TSO model, BSPs only interact with their own TSO, who in turn will exchange reserves with the other TSO [20], [21].

4. Cost-optimised activation of balancing energy

In last module, related to the activation phase, TSOs will coordinate the activation of their reserves according to a harmonised activation scheme. An example for this is a common merit order list where bids from all connected TSOs are put on a common platform, after which the market is cleared [22].

It is clear that the last three modules occur in the same order as the phases of the balancing market explained in 2.1. Currently, all considered countries take part in module 1. The other modules are less implemented but also important e.g. the cooperation between Belgium and the Netherlands for cross-border exchange of aFRR and mFRR [23].

3 Imbalance netting opportunity

To apply imbalance netting, first the netting potential has to be calculated, which can be done every second [18]. This is the amount of imbalance volumes that can be exchanged cross-border and is the minimisation of the following three terms. First, for imbalance netting to occur, the imbalance volumes, i.e. the difference between production and demand at a specific time, for both control areas, should have opposite directions. This means that when one TSO has too much production (or demand), the other TSO will have too much demand (or production) and thus this can be evened out. Of course, only the minimum of these imbalance volumes can be netted [18].

Second, there is a limit for the exchange for IGCC due to reliability requirements. This limit is approximately equal to the aFRR that is procured nationally and thus is different for each country [18].

Third, the interconnection capacity has to be available for netting to occur. This capacity is first allocated to the wholesale electricity markets (long term, day-ahead and intraday). However, there is no allocation mechanism for the balancing markets at present [8], [18]. So only when there is still capacity left after the wholesale market, this can be used for imbalance netting. However, it is not certain upfront if any capacity will be available, which hampers the balancing market both in short term, by not being able to net the imbalances, and in long term, by procuring too much locally to guarantee the availability of reserves.

Two options can be considered for the interconnection capacity. First, the Net Transfer Capacity (NTC) is the theoretical maximum, taking into account safety limits, of interconnection capacity that can be exchanged between control areas [24]. However, as this is the maximum before any exchange on the wholesale markets take place, this is not the most realistic option. Although, due to its simplicity, this can be a valid choice for interconnection values [7]. A second option is to take a Flow-Based Market Coupling (FMBC) approach. This has the advantage that values are more realistic but the trade-off is that calculations become more complex [7].

Furthermore, this interconnection capacity has to be available in the right direction. A positive imbalance cannot be exchanged if there is no interconnection capacity left in the direction to the control area with a negative imbalance. So depending on the directions of the imbalance volumes, the capacity of import or export direction is taken into account to calculate the netting potential.

The cost savings for the TSOs depend on the sign on their imbalance volumes:

1. TSO with negative imbalance: this TSO will save costs thanks to reducing the need to activate reserves. Therefore, the cost savings will be based on their price for upward regulation.
2. TSO with positive imbalance: the savings for this TSO depend on the sign of the price for downward regulation. Usually, the price is positive meaning that the TSO earns money by asking suppliers to regulate downwards. As suppliers will have less fuel costs, they want to pay money to the TSO in order to produce less. In this case, netting the imbalance will remove this payment and thus reduce revenue for the TSO. Therefore, the TSO has negative cost savings from the imbalance netting in this case. However, there are occasions where the downwards regulation price is negative, meaning that the TSO has to pay the supplier. In this case, the TSO has a positive cost saving.

To assign cost savings to the netting potential, this netting potential is multiplied with the saved costs from avoiding activation of reserves, i.e. the opportunity costs. To achieve a fair spread of the savings, the IGCC settlement price is used to determine side payments for the financial settlement of these cross-border exchanges [18]. This settlement price is calculated by taking the volume-weighted average of the opportunity prices of the participating countries [18]. Therefore, in the case of a TSO who will lose money due to imbalance netting, their loss will be offset by the settlement.

4 Model description

4.1 Objective

The model studies the imbalance netting potential and cost savings between Belgium and the Netherlands for the full year of 2015. Furthermore, interconnection capacity has been taken into account. The goal of this model is to check the differences between theoretical possible imbalance netting and the real netting that has occurred. Furthermore, the importance of sufficient interconnection capacity is tested by comparing the savings of the different scenarios.

4.2 Scenarios

Five main scenarios are presented in this paper (Table 1). The difference in the scenarios lies in two aspects: the interconnection capacity and the reliability limit. For the interconnection capacity, in the first three scenarios, this is set at the Available Transfer Capacity (ATC) at ID to get a realistic figure. For the last two scenarios, an upfront reservation of capacity is imposed. This means that there will always be a part on the interconnection available for balancing purposes. This number changes from 0 to 400 MW in case 4 and 0 to 150 MW in case 5. The reason for this difference in those two case is that the reliability limit will cause reservations of more than 150 MW to be redundant.

Case number	Interconnection capacity (MW)	Reliability limit (MW)
1 (real IGCC data)	ATC	150
2	ATC	150
3	ATC	/
4	Reserving capacity (0-400 MW)	/
5	Reserving capacity (0-150 MW)	150

Table 1 Overview of scenarios

For Belgium, the reliability limit is set on 140 MW, although this limit is not completely fixed and the data[1] shows an imbalance netting limit of 150 MW [18]. Therefore, the same limit of 150 MW is used in this paper for the respective scenarios. Furthermore, the limit for the Netherlands is higher at 300 MW so setting the limit at 150 MW will not be a problem. As this poses a rather strict constraint on the model, this constraint is removed for scenarios 3 and 4. Thus, it can be seen how this constraint affects imbalance netting.

Scenario 1 is a special case as here real data of IGCC exchanges is used and thus the model does not decide whether or not imbalances can be netted. This scenario is introduced to show the difference between the model and reality.

4.3 Data inputs and assumptions

Imbalance volume data is taken from the websites of the respective TSOs. For the Belgian imbalances, the System Imbalance[2] is used while for the Netherlands, the Settled Imbalances[3] are used [21].

aFRR prices are considered in the calculations as cost savings arise from dismissing activation of aFRR. For Belgium, the activated energy prices for aFRR[2] are used; for the Netherlands, the bid price ladder for 100 MWh[4] is used. The settlement payments are based on the IGCC settlement price. In Belgium, this price is calculated as a quantity weighted average of the offered aFRR prices [18]. Therefore, the aFRR price is used to calculate the side-payments in this paper. Furthermore, the aFRR price in Belgium was the same as the IGCC price for every QH in 2015[2].

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[1] Elia, "Data Download Page," 2016. [Online]. Available: http://www.elia.be/en/grid-data/data-download. [Accessed: 13-Sep-2016].

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The cost savings presented in this paper relate to the costs from activation of reserves. There are also the payments from and to the TSO from the Balance Responsibility Parties (BRP). However, these costs are out of the scope of this paper.

For the interconnection between Belgium and the Netherlands, the ATC[5] was used. These values are the ones during ID trading. This gives a more realistic view of the resting interconnection capacity available for balancing purposes than taking NTC values which are commonly used in previous similar studies. Also, the calculations are easier than for FBMC data. Therefore, the usage of ATC is viewed as a trade-off between the other NTC and FMBC. This does not mean that the ATC method is considered better than the others. However, it is interesting to see what the influence is of another method on the results.

For the real scenario (scenario 1), IGCC exchanged volumes data is also used in the model. The data on volumes for IGCC originate from the Belgian TSO[6]. As the data was from 2015 and France only joined IGCC in 2016, all the data for Belgium is related to the Dutch border, as Belgium only has interconnections with France and the Netherlands [18].

5 Results

First, the comparison of scenario 2 (ATC values) and scenario 5 (reserving interconnection capacity) is shown in Table 2. Here, the reliability limit is still imposed with a limit of 150 MW. Therefore, there is no reason to reserve more than 150 MW as this can never be used.

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[5] TenneT, “Beschikbare transportcapaciteit Intraday,” 2016. [Online]. Available: http://energieinfo.tennet.org/Connection/ATCIntradayCountry.aspx. [Accessed: 20-Sep-2016].

[6] Elia, “Data Download Page,” 2016. [Online]. Available: http://www.elia.be/en/grid-data/data-download. [Accessed: 13-Sep-2016].

Interconnection available?	Savings for Belgium	Savings for the Netherlands	Total savings
ATC (scenario 2)	€ 3,265,346.70	€ 1,142,022.67	€ 4,407,369.37
Reservation of 60 MW (scenario 5)	€ 5,453,334.31	€ 453,328.07	€ 5,906,662.39
Reservation of 150 MW (scenario 5)	€ 6,442,168.77	€ 102,938.94	€ 6,545,107.71

Table 2 Results of ATC versus reserving interconnection with aFRR limit

As interconnection capacity rises, savings for Belgium rise. These results are in line with what was expected: more capacity means more imbalance netting possibilities and thus more cost savings. However, for the Netherlands this is not true. Increasing the interconnection capacity will reduce the savings for it. An explanation for this can be that in times of no interconnection availability, the Dutch imbalances are rather positive than negative and they receive money from their own suppliers. By reserving interconnection capacity, the Netherlands will now transfer the imbalance to Belgium and they may receive less money in return. However, the total savings still rise so this is better for society but may induce new side payments from Belgium to the Netherlands.

Second, there is the case where the reliability limit is removed. Here, increasing reserved capacity over 150 MW is a valid option as now the full amount of imbalances can be netted, taking into account the remaining interconnection capacity. The results can be seen in Table 3. Again, the results rise for Belgium with rising interconnection reservation. And for the Netherlands, the savings drop significantly when more capacity is reserved so for this there is no difference between the case with and without the aFRR limit. However, this decrease is less than the increase for Belgium hence total savings still rise.

Interconnection available?	Savings for Belgium	Savings for the Netherlands	Total savings
ATC (scenario 3)	€ 3,369,973.76	€ 1,173,887.20	€ 4,543,860.96
Reservation of 100 MW (scenario 4)	€ 6,230,880.11	€ 248,852.06	€ 6,479,732.17
Reservation of 200 MW (scenario 4)	€ 6,609,706.92	€ 118,306.80	€ 6,728,013.72
Reservation of 300 MW (scenario 4)	€ 6,626,947.01	€ 116,516.87	€ 6,743,463.88
Reservation of 400 MW (scenario 4)	€ 6,626,470.01	€ 117,581.87	€ 6,744,051.88

Table 3 Results of ATC versus reserving interconnection without aFRR limit

The complete results for this scenario are illustrated in Figure 2. This shines a light on another interesting result. The total savings flatten out and this starts at around 150 MW of reserved capacity, which is also the reliability limit for cross-border exchange of balancing reserves. Therefore, the importance of this aFRR limit while discussing imbalance netting can be viewed as rather low: the extra cost savings from removing this limit are minor. Taking this limit as the limit for the reservation, there is still an improvement of almost 50% compared to no reservation at all.

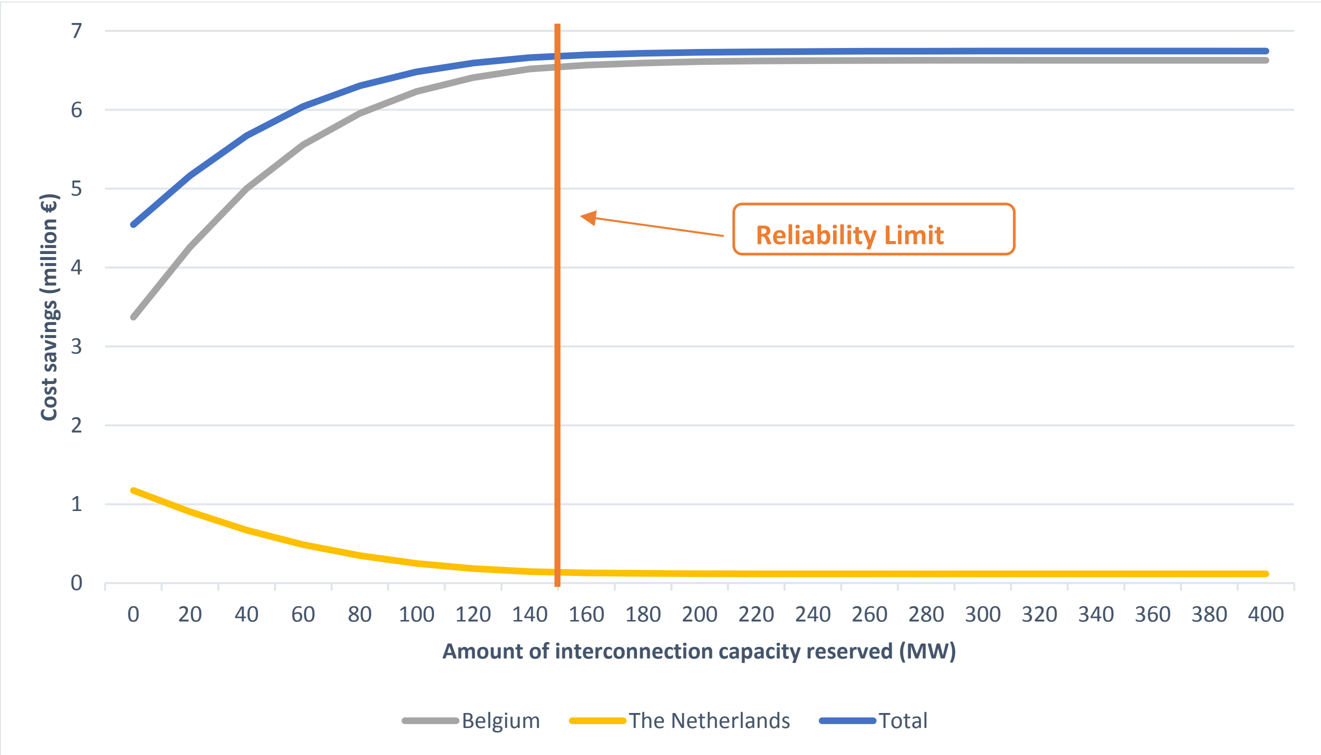

Figure 2 Cost savings per amount of reserved interconnection capacity

Cost savings also differ significantly across several months (Figure 3). For two months, January and July, the savings for the Netherlands are negative. These months both have mostly negative imbalance volumes for Belgium and positive imbalance volumes for the Netherlands which causes savings to drop for the Netherlands. However, overall cost savings remain positive so there is still value for imbalance netting in these periods.

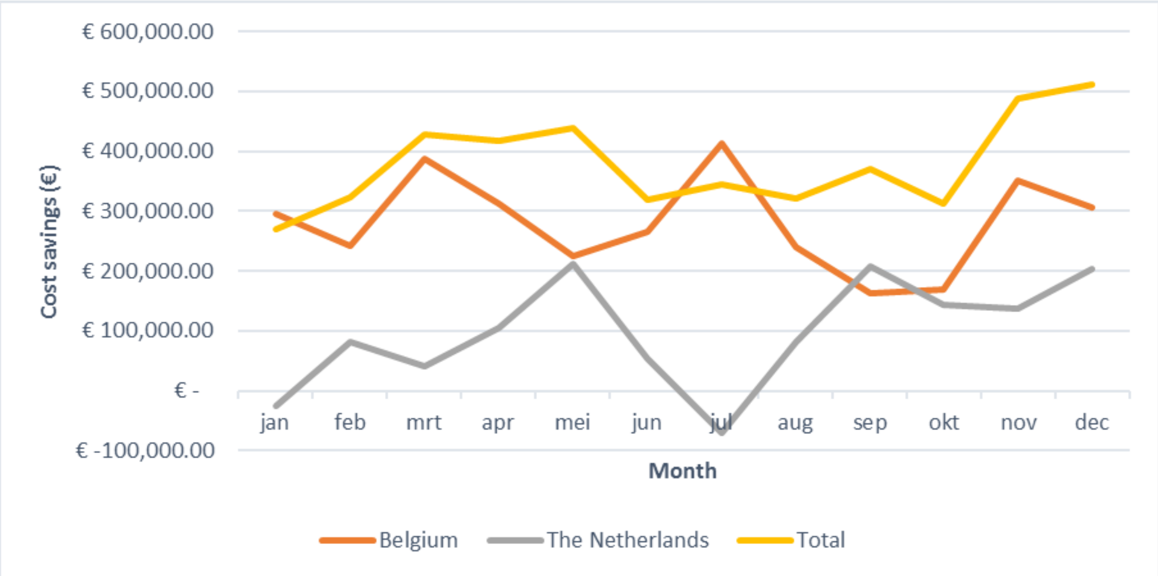

Figure 3 Monthly comparison of cost savings

Comparing the results from scenario 2 (realistic case) with scenario 1 (real case) gives a view on how the model compares with reality. There is a discrepancy in these numbers. The total amount of IGCC in real life is almost twice as much as would be expected from the model. A reason for this is that imbalance netting can only be applied for QH in this model while real IGCC can be applied every second [18]. Therefore, while the imbalances for a specific second in a specific QH can be opposite and thus netting can be applied, this will not always be the case for that specific QH while aggregated which explains this discrepancy.

6 Conclusion and future work

Balancing reserves play a crucial part in stabilising future power systems. The exchange of these reserves in the several phases of the balancing market could result in significant cost savings. This paper shows that increasing the interconnection capacity for imbalance netting will not yield the same results for all participants. However, the total cost savings always increase which opens up the opportunity of side-payments. These total cost savings can rise with about 50%.

As only the benefits on the balancing market are considered here, future work could focus on the impact of reserving this interconnection upfront and thus not being able to use this capacity for the DA market. This will result in a loss of profit in the DA market. Therefore, this present an opportunity to search the optimal trade-off between the usage of interconnection capacity for DA and the balancing market. Further research can also focus on other modules of the IGCC collaboration and what the impact of interconnection is on these.

Taking into account the results of this paper, interconnection capacity is confirmed as a vital part of cross-border balancing. This will provide opportunities to further enhance the efficiency of a European wide electricity market.

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